UNIVERSITY OF MANNHEIM

Philipps Universität Marburg

Foundations of Statistical Modeling II

SMiP Core Course, Spring 2020

Edgar Erdfelder & Daniel W. Heck

STATISTICAL MODELING in PSYCHOLOGY

FREIBURG HEIDELBERG LANDAU MANNHEIM TÜBINGEN

Foundations of Statistical Modeling II

Multinomial Processing Tree (MPT) Modeling: Basic Methods and Recent Advances, Block 1

Edgar Erdfelder and Daniel W. Heck

University of Mannheim & Phillips University Marburg

1) Basics

- 1.1) Introduction to standard MPT models
- 1.2) Examples
- 1.3) Model development
- 1.4) Formal model structure
- 1.5) Identifiability
- 1.6) Parameter estimation
- 1.7) Model assessment
- 1.8) Selected literature

1.1) Introduction to standard MPT models

- **Required type of data:**
- Standard multinomial models are tailored to discrete (i.e., categorical) data.
- Psychological data are typically discrete in nature (e.g., yes/no responses, correct/incorrect judgments, ratings, choices, ...).
- If not, they can be transformed into discrete data
  - Response times: Categorization into bins
  - Numerical judgments: Rank-orders of judgments
- Hence, many psychological paradigms generate frequency data that are appropriate for MPT modeling.

1.1) Introduction to standard MPT models

- **Distributional assumptions:**
- Standard MPT models assume that observations are sampled independently from
  - one multinomial distribution (simple multinomial model)
  - several multinomial distributions (joint multinomial model)
- This includes simple and joint binomial models as special cases.
- The frequency data structure can be univariate or multivariate.

MPT models ...

- … provide explanations of observed frequency data in terms of basic parameters with clear-cut psychological interpretations;
- … these parameters represent probabilities of latent psychological processes (or latent psychological states) underlying human behavior;
- … in other words, these models measure the contributions of different psychological processes to frequencies of observable behaviors.
- In this sense, multinomial models allow for a "measurement of cognitive processes" (Riefer & Batchelder, 1988)

1.2) Examples

A very simple example:

- *Paradigm:*
  - Yes-No recognition test
- *Two Conditions:*
  - Old Items
  - New Items
- *Categorical (dichotomous) dependent variable:*
  - „Old“ vs. „New“ Judgment

A) One-High Threshold Model (Blackwell, 1963)

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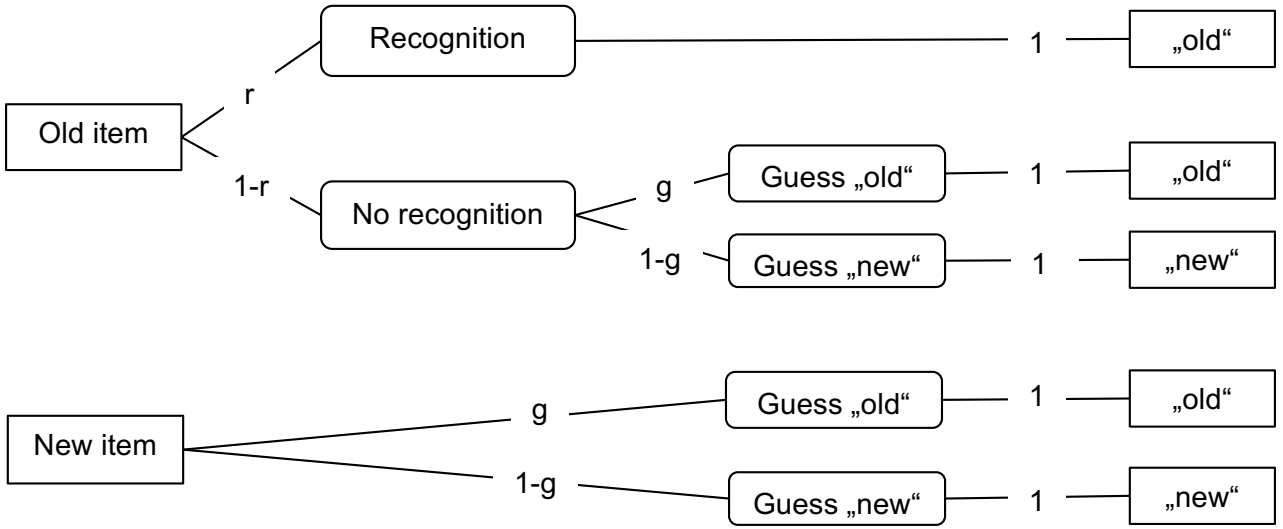

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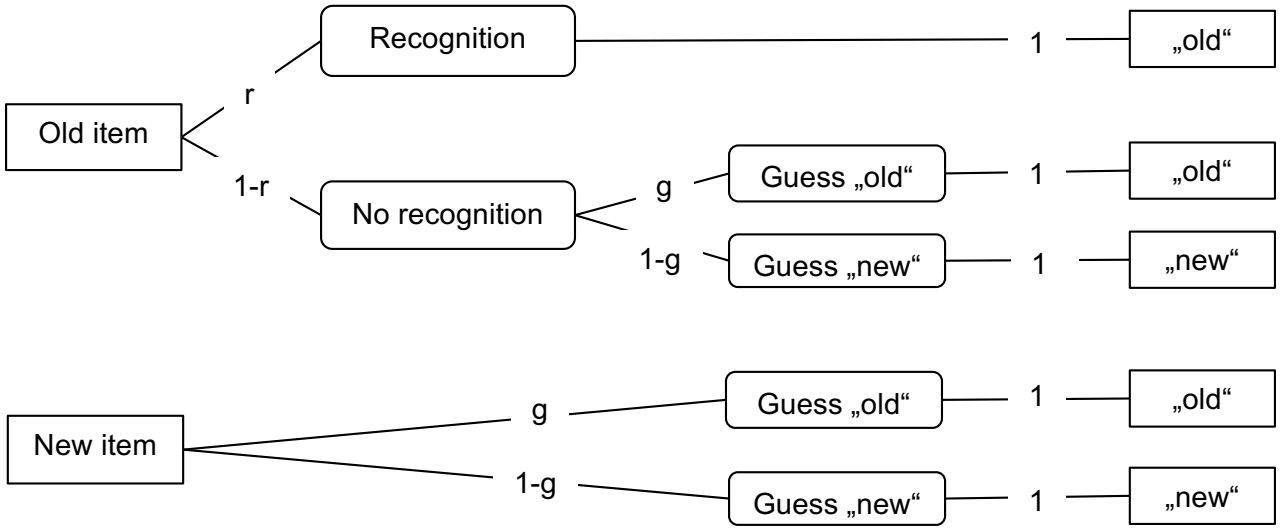

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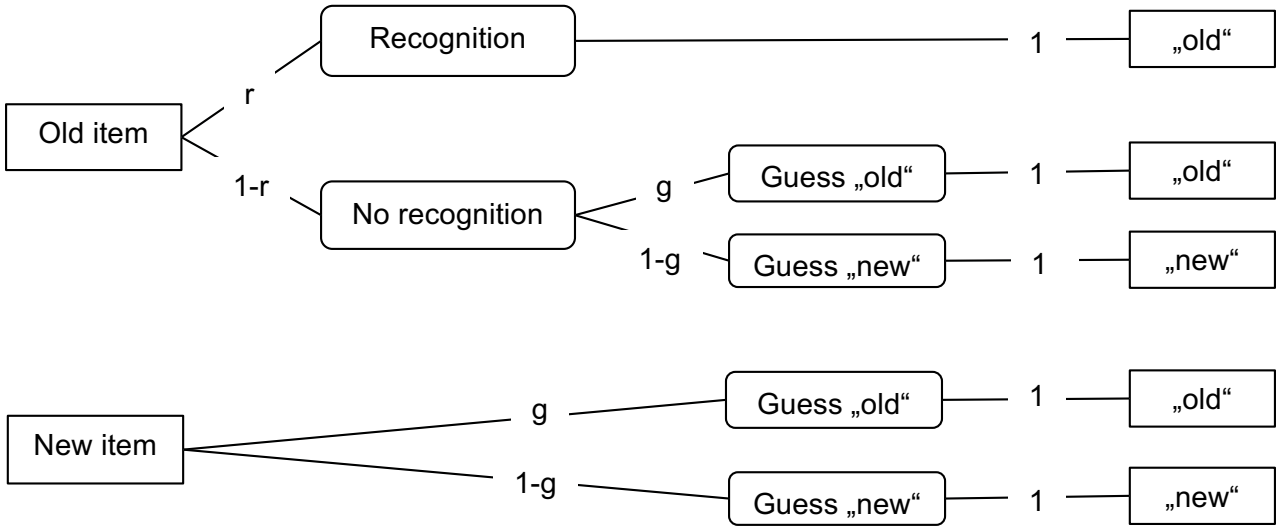


Model equations:

$p(\text{„old“} \mid \text{old item}) = r + (1-r) \cdot g$

$p(\text{„old“} \mid \text{new item}) = g$

B) Measuring storage and retrieval in long-term memory

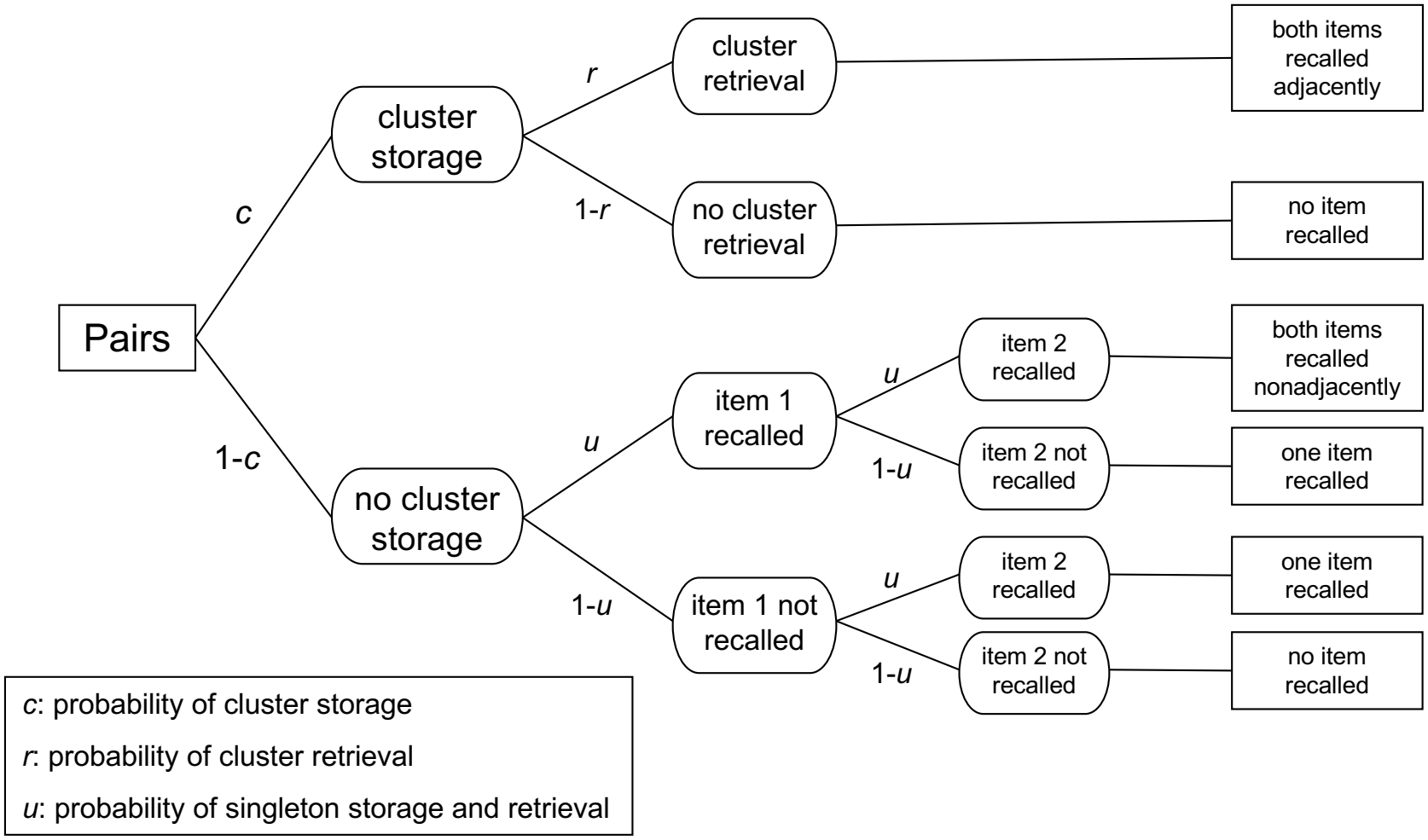
- *Empirical Paradigm*:
  - Free recall of word list consisting of
    - Word pairs (e.g. „chair“ und „table“)
    - Singletons (e.g., „rose“ and no other flower).
    - „Primacy–“ and „Recency–Buffer“.
- *Two distributions of responses*:
  - pairs
  - singletons

Scoring of responses

- Observation categories
  - For word pairs:
    - E1 — both words recalled adjacently
    - E2 — both words recalled nonadjacently
    - E3 — one word recalled
    - E4 — no word recalled
  - For singletons:
    - F1 — Recalled
    - F2 — Not recalled

Storage-Retrieval Model

(Batchelder & Riefer, 1980, 1986)



Model equations

- *Word pairs*:
- $p(\mathrm{E}_1) = c \cdot r$
- $p(\mathrm{E}_2) = (1 - c) \cdot u^2$
- $p(\mathrm{E}_3) = (1 - c) \cdot 2 \cdot u \cdot (1 - u)$
- $p(\mathrm{E}_4) = c \cdot (1 - r) + (1 - c) \cdot (1 - u)^2$
- *Singletons*:
- $p(\mathrm{F}_1) = u$
- $p(\mathrm{F}_2) = 1 - u$

1.3) Model development

- Preliminary summary:
- Select a paradigm (e.g., a task)
- Define the conditions of the paradigm
- Define the category system for each condition
- List relevant processes/parameters
- Construct theoretically reasonable processing branches („trees“) for each condition
- Derive corresponding model equations.
- General rules:
  - As simple as possible!!
  - Ignore unlikely events